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COACHING & KINESIOLOGY

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Postural performance while boxing with an opponent versus practice with a boxing bag

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Abstract

Background. Boxing with an opponent may have a more important effects on postural control than hitting a punchbag. It might be vital for a boxer to know what happens to their body control after a slugfest.

Problem and aim. We predicted that postural sway would be increased by fatigue after bouts under Bout and Bag conditions. Our other hypothesis was that sway in boxers after a bout would be higher after actual bouts than after a punchbag routine.

Methods. Eleven active male boxers (age = 22.73 ± 4.15 years) volunteered to participate in the study. We measured the subjects' heart rate, blood lactate, and postural sway. We evaluated postural sway using the Biodex Balance System (BBS) on the dominant foot. Using a within-subjects design, each subject participated in two experimental conditions: Boxing with an opponent (*Bout*) and boxing with a punchbag (*Bag*). In each condition, we collected data six times: before boxing, after each round, and 10 and 20 minutes after boxing.

Results. At Round 2, OSI scores were higher in the Bout condition than the Bag condition ($t = 2.153$; $p = 0.044$). For the Bout condition, the OSI scores in Round 1 and Round 2 were higher than in Pre-boxing (For Round 1, $p = 0.031$; for Round 2, $p = 0.024$) and in Recovery 20 (For Round 1, $p = 0.044$; for Round 2, $p = 0.006$). In the Bag condition, Recovery 20 had lower OSI score than Round 1 ($p = 0.027$).

Conclusions. Our results suggest that competitive bouts impose greater challenges on postural control than working a punchbag, and that these differences are independent of general boxing-related fatigue.

Introduction

Maintaining postural control under static or dynamic conditions is essential for daily life activities and physical activities. Sensorial information derived from vestibular, visual and somatosensorial systems allows to maintain a balanced position of body. Motor commands is initiated after the information from afferent neurons is processed in brain stem. All three sensory systems contribute to maintaining a balanced position, and any of these systems or damage to the brain stem or cerebellum will adversely affect the postural control mechanism [Leppers *et al.* 1997]. Inability to generate the needed or expected power for performing any activity is defined as fatigue [Ives 2014]. Fatigue is also a factor affecting postural control [Noakes 2000; Larson, Brown 2018]. Fatique decreases proprioceptive and kinestetic properties of joints. It increases the decharge thereshold of muscle spindles, which disrups afferent feedback after changes in joint sensitivity [Gribble *et al.* 2004]. Studies which analysed muscular fatigue have been indicated an increase of postural sway after fatiguing exercise [Wilkins *et al.* 2004; Erkmen *et al.* 2009; Nardone *et al.* 1997; Larson, Brown 2018]. Postural sway recovery occurs in 10 – 20 min after physical activity [Khanna *et al.* 2008; Susco *et al.* 2004; Nardone *et al.* 1997; Erkmen *et al.* 2010].

The ability of athletes to maintain a balanced stance develops in accordance with the structure of the sports branch [Vuillerme et al. 2001; Davlin 2004; Hrysomallis 2011; Mkaouer *et al.* 2017]. It is important in a balanced stance in boxing, as in many sports. Boxing-specific movements are started by a strong foundation of a balanced stance. This stance position lets a boxer to exchange quickly between defensive and offensive actions. Also, it makes easier to maintain the center of gravity and the ability to move [Dumas, Dumas 2013].

Boxing depends heavily upon skillful control of dynamic posture. During boxing bouts, boxers often generate a succession of small hops or bounces. Even when the feet are stationary, boxing comprises almost constant movement of the body as the boxer shifts his or her weight forward, back, and side to side in feints, or to dodge punches thrown by the opponent. In bouts, boxers can be seen moving around. These characteristics of bouts contrast with boxers' behavior when practicing with a punchbag. When "working the bag", movement of the feet is reduced, and locomotion is virtually eliminated.

We are not aware of any previous studies in which researchers have evaluated postural activity in relation to the distinction between bouts (i.e., boxing versus an opponent) and solo practice punching a punchbag.

Boxing can be very vigorous, demanding the rapid expenditure of a great deal of energy, and even experienced boxers can quickly become fatigued. Heart rate and blood lactate levels are commonly used measures of fatigue [Couts *et al.* 2009]. Heart rate and blood lactate levels have been evaluated in relation to boxing, showing how these measures change (relative to baseline) during and after boxing [Ghosh 2010].

Fatigue can affect postural activity in upright stance [Gauchard *et al.* 2002]. There have been no direct comparisons of physiological measures (heart rate, blood lactate levels) with measures of postural performance in boxers. Accordingly, in the present study one of our aims was to evaluate the time course of boxing-related changes in heart rate, blood lactate levels, and postural performance.

In the present study, we focused on postural activity. We predicted that postural sway would increase by fatigue after bouts in both two experiment conditions. Our other hypothesis was that sway after bout in boxers would be higher than after actual bouts than after a punchbag.

Materials and Methods

Participants

Eleven active male boxers (age = 22.73 ± 4.15 years, height = 177.82 ± 4.24 cm, body mass = 71.27 ± 11.75 kg, sport experience = 7.09 ± 3.83 year) volunteered to participate in the study. All boxers have experience in international competition and no neurological or movement disorders and recent injury of the lower extremities in the last 6 months. All participants provided signed consent to the study procedures before testing. The study protocol was approved by the Faculty's Ethics Committee at Selçuk University.

Apparatus

We evaluated postural sway using the Biodex Balance System, or BBS (Biodex, Inc.). The BBS included a circular force plate that could rotate up to tilt 20° in two axes, forward-backward, side-to-side, or any combination of these. The device can vary the resistance to rotation, with 12 preset levels of resistance. Level 1 represents the most resistance while level 12 depicts the least resistance. The instantaneous angular position of the force plate was recorded by the BBS system. BBS software calculates an *overall stability index*, or OSI, which is a summary score representing a person's overall postural performance [Aydog *et al.* 2006; Testerman, Vander Griend 1999]. The OSI scales negatively with stability, such that high OSI scores correspond to reduced postural performance. The BBS has been extensively validated [Testerman, Vander Griend 1999; Arnold, Schmitz 1998; Cachupe *et al.* 2001; Karimi *et al.* 2008].

Blood lactate level was evaluated using a portable lactate analyzer (Lactate Scout, SensLab, Leipzig, Germany), with blood samples taken from the fingertip [Tanner *et al.* 2010]. Heart rate monitors (RS 800, Polar Vantage NV, Polar Electro Oy, Finland), which registered beats per minute in 5-second intervals, were used to measure subjects' heart rate.

Procedure

In a within-subjects design, each subject participated in two experimental conditions: Boxing with an opponent (*Bout*) and boxing with a punchbag (*Bag*). The order of conditions varied randomly between subjects. In the bout condition, matches were conducted according to the rules of the International Boxing Association (AIBA) for male boxers, under which there were 3 rounds, with each round lasting 3-minutes, and 1-minute rest period between rounds. The bag condition was identical in format and temporal structure; the only difference was the use of a punchbag, rather than a live opponent. For individual participants, Bout and Bag sessions were separated by at least three days. In each condition, we collected data six times: before boxing, after each round, and 10 and 20 minutes after boxing. The dependent variables were heart rate, blood lactate level, and postural performance. Boxers were encouraged during bouts by their coaches.

Postural sway

The resistance level of the Biodex was set at 8. BBS testing was conducted without footwear, while standing on the dominant foot. We determined subjects' dominant foot by asking them a question: "Which foot do you prefer to kick a ball?" Participants were instructed to keep the non-dominant leg flexed approximately 90° at the knee, and to stand with their arms crossed, with their hands on their shoulders. Before boxing, we determined the foot placement that would ensure the participant's center of gravity was centered on the device. The Biodex screen provided real-time data about sway, with the center of gravity presented as a dot moving on an *x-y* plot. Standing on his dominant foot, the participant adjusted their foot position until the center of gravity was set in the center of the *x-y* plot on the screen. For each participant, this foot position was marked with a tape and used in all postural sway measurements. To familiarize participants with the actual testing procedure, each participant was given three practice trials with the 20-second balance testing procedure. Data were not recorded during these practice trials. The duration of the pre-test was approximately 5 minutes.

For postural test trials, the participant place their preferred foot on the marked position on the BBS force plate, again bending the non-preferred leg at the knee, and with the arms crossed and the hands on the shoulders. In this position, they attempted to keep the rotating force place "as flat and still as possible" for 20 sec. During postural testing the BBS display panel was turned off, and participants looked at a fixation point at eye level and one meter away. During bouts, BBS data were collected during the 1-minute break between rounds.

Heart Rate

We measured the heart rate 6 times before, during and after each set and at the 10th and 20th minutes after boxing. Before the tests, each subject wore a chest strap of the heart rate monitor and its watch. Subjects' heart rates during the tests were read from heart rate monitor and recorded.

Blood Lactate

Blood lactate was measured simultaneously with the heart rate. Blood samples were taken from the fingertip. The measurements were performed 6 times before, during and after each set and at the 10th and 20th minutes after boxing. The lactate analyser produced the results of the blood lactate in 10 seconds after taking a blood sample.

Statistical Analyses

All data were presented as the mean and standard deviation (SD). For each dependent variable, we conducted 2 × 6 repeated measures ANOVAs on factors Conditions (bout vs. bag) and Time. We conducted independent *t*-tests to compare the conditions and Bonferroni multiple comparison test to determine differences within subjects. An alpha level of 0.05 was used for all statistical tests. Data analysis was performed with SPSS 22.0 (SPSS Inc, Chicago, IL).

1. Results

The HR and LA concentration means ± SDs in experiment conditions can be seen in Table 1. Data on heart rate are summarized in Figure 1. The main effect of Conditions was not significant, $F_{(1\text{-}20)} = 3.36$, $p = 0.08$, but the main effect of Time was significant, $F_{(5\text{-}100)} = 1442.15$, $p < .001$, $n^2 = 0.99$). The Conditions × Time interaction was not significant, $F_{(5,100)} = 0.52$, $p = 0.76$. In the *Bout* condition, heart rate at pre-boxing was lower than at each of the other measurement times. In addition, after round 3 heart rate was higher than after round 1, or round 2. When measured 10 minutes and 20 minutes

Table 1. Heart rate and blood lactate concentrations in the Bout and the BBag conditions (Mean±SD).

	Pre-boxing	Round 1	Round 2	Round 3	Recovery 10	Recovery 20
HR (bpm)						
Bout	72.55±10.9	183.91±9.2 [a]	184.73±8.1 [a]	190.36±10.4 [a,b,c]	111.82±9.8 [a,b,c,d]	101.64±8.1 [a,b,c,d,e]
BBag	70.00±11.6	179.00±5.9 [a]	182.09±5.5 [a]	184.27±6.1 [a,b,c]	104.36±7.6 [a,b,c,d]	96.00±6.1 [a,b,c,d,e]
LA (mMol)						
Bout	1.65±0.4	8.06±1.2 [a]	10.29±2.3 [a,b]	11.59±2.4 [a,b]	8.65±2.3 [a,d]	5.77±2.3 [a,c,d,e]
BBag	1.35±0.3	9.76±2.4 [a]	11.81±1.7 [a,b]	11.37±2.6 [a]	8.00±2.4 [a,c,d]	5.25±1.9 [a,b,c,d,e]

[a] Significant difference from Pre-test (p<0.05). [b] Significant difference from Round 1 (p<0.05).[c] Significant difference from Round 2 (p<0.05). [d] Significant difference from Round 3 (p<0.05). [e] Significant difference from Recovery 10 (p<0.05).

Tablo 2. Boxers' OSI scores in the Bout and the BBag conditions (Mean±SD).

	Pre-boxing	Round 1	Round 2	Round 3	Recovery 10	Recovery 20
Bout	1.92±0.6	3.54±1.6 [a]	3.39±1.4 [a]	2.88±1.3	2.10±0.6	2.01±0.8 [b,c]
BBag	1.89±0.5	2.55±0.9	2.43±0.6 [*]	2.12±0.9	2.01±0.9	1.89±0.7 [b]

[a] Significant difference from Pre-boxing (p<0.05). [b] Significant difference from Round 1 (p<0.05). [c] Significant difference from Round 2 (p<0.05). [*] Significant difference from BBag group (p<0.05).

after boxing, the heart rate was lower than when measured immediately after each boxing round. Finally, the heart rate was lower than when measured 10 minutes after boxing when measured 20 minutes after boxing. The identical pattern of post-hoc *t*-test results was observed for heart rate in the Bag condition.

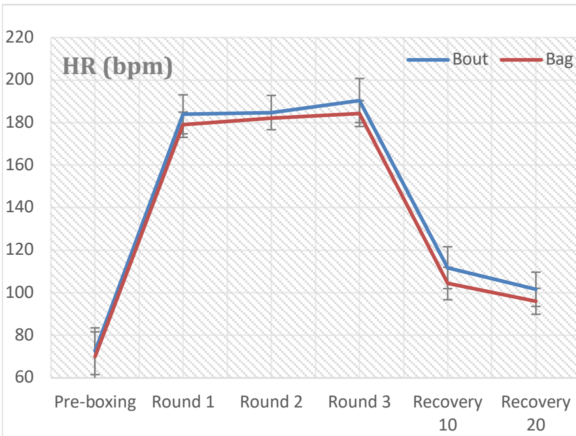

Figure 1. Mean heart rate in the Bout and the Bag conditions.

Data on blood lactate level are summarized in Figure 2. The main effect of Condition was not significant, $F_{(5,20)} = 0.14$, $p = 0.71$, $n^2 = 0.01$, but was the main effect of Time was significant, $F_{(5,100)} = 153.64$, $p < 0.001$, $n^2 = 0.89$. For both the Bout and Bag conditions, blood lactate level was lower before boxing than for all other times. For the Bout condition, in round 2 and Round 3 had higher blood lactate level than Round 1. Blood lactate level in Recovery 10 was lower than Round 3, and Recovery 20 blood lactate level was lower than Round 2, Round 3 and Recovery 10. In the Bag condition, blood lactate level significantly increased after bouts. Round 2 had higher blood lactate level than Round 1 and Round 3. Blood lactate level started to decrease after boxing, and in recovery 10 was lower than Round 3. Recovery 20 had lower blood lactate level than 3 Rounds and Recovery 10. There was a significant Condition × Time interaction for blood lactate level, $F_{(5,100)} = 3.07$, $p = 0.01$, $n^2 = 0.03$, suggesting that blood lactate level concentrations rose more rapidly in the Bag condition than in the Bout condition (Figure 2). However, post-hoc *t*-tests did not reveal a significant difference for any of the individual comparisons.

Table 2 and Figure 3 illustrate subjects’ OSI scores in both conditions. The main effect of the conditions was not significant, $F_{(5,100)} = 2.25$, $p = 0.15$. However, the main effect of Time was significant, $F_{(5,100)} = 13.16$, $p < 0.001$, $n^2 = 0.40$, as was the Conditions × Time interaction, $F(5,100) = 2.80$, $p = 0.02$, $n^2 = 0.12$. At Round 2, OSI scores were higher in the Bout condition than the Bag condition ($t = 2.153$; $p = 0.044$). For the Bout condition, the OSI scores in Round 1 and Round 2 were higher than in Pre-boxing (For Round 1, $p = 0.031$; for Round 2, $p = 0.024$) and in Recovery 20 (For Round 1, $p = 0.044$; for Round 2, $p = 0.006$). In the Bag condition, Recovery 20 had lower OSI score than Round 1 ($p = 0.027$).

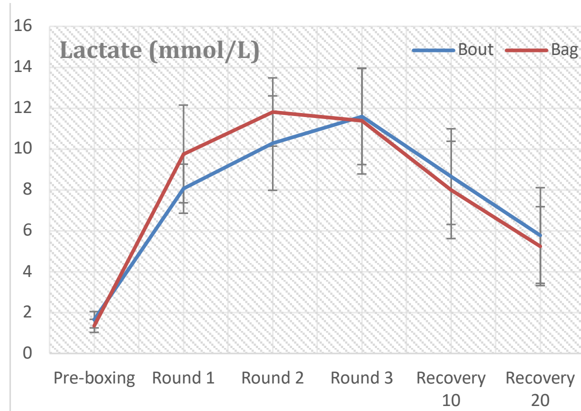

Figure 2. Mean blood lactate level concentrations in the Bout and the Bag conditions.

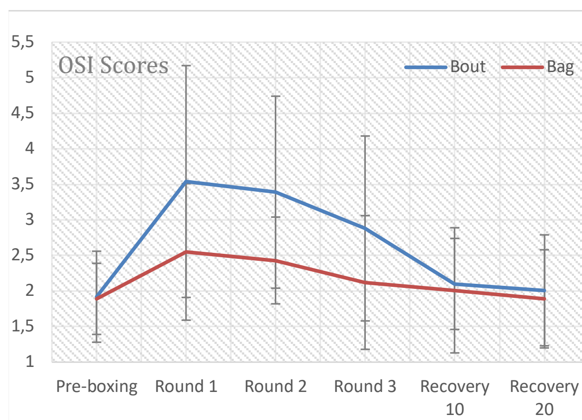

Figure 3. Mean postural performance (OSI scores) in Bout and Bag conditions.

2. Discussion

The study focused on heart rate, blood lactate and postural sway when boxing with an opponent or boxing with a punching bag. We evaluated heart rate, blood lactate levels and postural performance among boxers before, during, and after participation in actual bouts versus punching a bag. All measures changed during boxing, and returned to baseline or near-baseline levels 20 minutes after boxing. Heart rate did not differ as a function of conditions (bout vs. bag). During boxing, levels of blood lactate rose more rapidly in the bag condition than in the bout condition, but the effect was small. By contrast, postural performance during boxing was lower in the Bout condition than in the Bag condition. The results reveal novel relations between physiological and postural consequences of boxing.

As expected, after boxing started, blood lactate level and heart rate rapidly increased and reached their highest level after Round 3. It was observed that after 20 min recovery period, blood lactate level and heart rate which decreased in recovery process were higher than pre-boxing. Blood lactate level and heart rate did not differ between the Bout and the Bag in pre-boxing, Rounds and recovery periods. These results suggest that boxers had same exercise intensities in the Bout and the Bag conditions.

Amateur boxing is characterized as a high-intensity sport and athletes, in part because short rest periods between rounds are not sufficient for recovery [Guidetti *et al.* 2002]. Boxers need high anaerobic as well as aerobic capacity to be successful. Boxers' heart rate and blood lactate level after bout were declared as 178 beats/min and 8.24 mMol/l, respectively [El-Ashker, Nasr 2012]. In another study, boxers' heart rate after exercising was reported as 195±7 beats/min [Guidetti *et al.* 2002]. El-Ashker, Nasr [2012] found that boxers' heart rates were 197 ± 5.8 beats/min and 204 ± 7.2 beats/min after exhaustion exercising on a treadmill and dropped to 139 ± 7.1 and 128 ± 5.1 in the 3rd minute of the recovery. They found that blood lactates were 8.7 ± 1.1 and 7.3 ± 1.0 mMol/l after exhaustion exercising on a treadmill. El-Ashker *et al.* [2018] reported that in a 3-set boxing match, the highest heart rate was determined at the end of 3 sets. Kılıc *et al.* [2019], Ouergui *et al.* [2016] and Ghost [2010] found that boxers had higher lactate levels after boxing match compared to their baseline levels. Our results in relation to heart rate and blood lactate level were consistent with the studies of Ghost [2010], Guidetti *et al.* [2002], Ashker *et al.* [2018], El-Ashker, Nasr [2012], Kılıc *et al.* [2019], Ouergui *et al.* [2016].

The results of this study revealed that boxers' postural sway increased during boxing. This increase in postural sway may result from the disruptive effect of fatigue [Alderton, Moritz 1996; Nardone *et al.* 1997; Lundin *et al.* 1993; Ochsendorf *et al.* 2000; Larson, Brown 2018; Lepers *et al.* 1997; Wilkins *et al.* 2004]. Nevertheless, postural sway in the Bout condition was higher than the Bag condition. One possible explanation for this condition effect is that competitive bouts mandate frequent changes in dynamic posture, including foot placement, with rapid responses to sudden attacks from the opponent. When punching a bag, the need for changes in foot placement is reduced, and the need to generate rapid postural response to sudden attacks is absent.

Contradictory to our results, Di Virgilio *et al.* [2019] declared that postural control did not change immediately after boxing with an opponent (3 x 3-minute rounds with 2-minute rest in between each round) although numerous studies showed that strenuous effort has a disruptive effect on postural control. This may be due to Di Virgilio *et al.* [2019] using 2-minute rest intervals between bouts.

Perhaps our most novel finding was that, during boxing, postural performance differed between the Bout and Bag conditions, but that these differences appeared to be independent of both heart rate and blood lactates. It is important to note that the effect size for the Condition × Time interaction for postural performance was larger than the effect size for the Condition × Time interaction for blood lactates, a fact that is reflected in the presence of statistically significant post-hoc tests only for the postural data.

Our results are consistent with previous studies showing that fatigue-related changes in postural activity return to baseline in about 20 minutes [Khanna *et al.* 2008; Nardone *et al.* 1997; Susco *et al.* 2004; Yaggie, McGregor 2002; Larson, Brown 2018]. Our results about the recovery of sway suggested the increase during bout can be a temporary effect of bout on body balance control.

Due to the short recovery time between bouts (1 min), the postural sway of the boxers in this study could only be measured with eyes open. The results of this study were therefore limited to postural sway in the open condition.

Conclusions

In conclusion, our results indicate that, during boxing, changes in heart rate and blood lactates were at least partially independent from changes in postural performance. This conclusion is based on the absence of any condition effects in our heart rate data, and in the difference in condition effects between the data on blood lactates and postural performance. Our results suggest that competitive bouts impose greater challenges on postural control than working a punching bag, and that these differences are independent of general boxing-related fatigue.

Funding sources and compliance with ethical standards

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There is no financial or other relationship that might lead to conflict of interest. The study design has been approved by the Faculty's Ethics Committee at Selçuk University.

References

1. Alderton A.K., Moritz U. (1996), *Does calf-muscle fatigue affect standing balance?,* "Scand J Med Sci Sports", vol. 6, pp. 211–215; doi: 10.1111/j.1600-0838.1996.tb00093.x.
2. Arnold B.L., Schmitz R.J., (1998), *Examination of balance measures produced by the Biodex Stability System,* "J Athl Training", vol. 33, pp. 323-327.

3. Aydog E., Depedibi R., Bal A., Eksioglu E., Unlu E., Cakci A. (2006), *Dynamic postural balance in ankylosing spondylitis patients*, "Rheumatology", vol. 45, no. 4, pp. 445-448; doi: 10.1093/rheumatology/kei192.
4. Cachupe W.J.C., Shifflett B., Kahanov L., Wughalter E.H. (2001), *Reliability of Biodex Balance System measures*, "Meas Phys Educ Exerc Sci", vol. 5, pp. 97-108; doi: 10.1207/S15327841MPEE0502_3
5. Couts A.J., Rampinini E., Marcora S.M., Castagna C., Impellizzeri F.M. (2009), *Heart rate and blood lactate correlates of perceived exertion during small sided soccer games*, "J Sci Med Sport", vol. 12, pp. 79-84; doi: 10.1016/j.jsams.2007.08.005.
6. Davlin C.D. (2004), *Dynamic balance in high-level athletes*, "Percept Mot Skills", vol. 98, pp. 1171–1176; doi: 10.2466/pms.98.3c.1171-1176.
7. Di Virgilio T.G., Ietswaart M., Wilson L., Donaldson D.I., Hunter A.M. (2019), *Understanding the consequences of repetitive subconcussive head impacts in sport: brain changes and dampened motor control are seen after boxing practice*, "Front Hum Neurosci", vol. 13, p. 294; doi: 10.3389/fnhum.2019.00294.
8. Dumas A., Dumas J. (2013), *Successful boxing: the ultimate training manual*, Crowood Press, Wiltshire, UK.
9. El-Ashker S., Chaabene H., Negra Y., Prieske O., Granacher U. (2018), *Cardio-respiratory endurance responses following a simulated 3 × 3 minutes amateur boxing contest in elite level boxers*, "Sports", vol. 6, p. 119; doi:10.3390/sports6040119.
10. El-Ashker S., Nasr M. (2012), *Effect of boxing exercises on physiological and biochemical responses of Egyptian elite boxers*, "J Phys Ed Sport", vol. 12, pp. 111–116; doi: 10.7752/jpes.2012.01018.
11. Erkmen N., Taskın H., Kaplan T., Sanioglu A. (2010), *Balance performance and recovery after exercise with water intake, sport drink intake and no fluid,* "J Exerc Sci Fit", vol. 8, no. 2, pp. 105-112.
12. Erkmen N., Taskın H., Kaplan T., Sanioglu A. (2009), *The effect of fatiguing exercise on balance performance as measured by the balance error scoring system*, "Isokinet Exerc Sci", vol. 17, no. 2, pp. 121-127.
13. Gauchard G.C., Gangloff P., Vouriot A., Mallie J.P., Perrin P.P. (2002), *Effects of exercise-induced fatigue with and without hydration on static postural control in adult human subjects*, "Int J Neurosci", vol. 112, pp. 1191-1206; doi: 10.1080/00207450290026157.
14. Ghosh A.K. (2010), *Heart rate, oxygen consumption and blood lactate responses during specific training in amateur boxing*, "International Journal of Applied Sports Sciences", vol. 22, no. 1, pp. 1-12; doi: 10.24985/ijass.2010.22.1.1.
15. Gribble P.A., Hertel J., Denegar C.R., Buckley W.E. (2004), *The effects of fatigue and chronic ankle instability on dynamic postural control*, "J Athl Train", vol. 39, no. 4, pp. 321–329.
16. Guidetti L., Musulin A., Baldari C. (2002), *Physiological factors in middleweight boxing performance,* "J Sports Med Phys Fit", vol. 42, no. 3, pp. 309-314.
17. Hrysomallis C. (2011), *Balance ability and athletic performance,* "Sports Med", vol. 41, pp. 221–232; doi: 10.2165/11538560-000000000-00000.
18. Ives J.C. (2014) *Motor behavior: connecting mind and body for optimal performance*, Lippincott Williams & Wilkins, Philadelphia, PA, USA.
19. Karimi N., Ebrahimi I., Kahrizi S., Torkaman G. (2008), *Evaluation of postural balance using the Biodex balance system in subjects with and without low back pain*, "Pak J Med Sci (Part-II)", vol. 24, pp. 372-377.
20. Khanna P., Kapoor G., Zutshi K. (2008), *Balance deficits and recovery timeline after different fatigue protocols,* "Indian J Physiother Occup Ther", vol. 2, pp. 42-54.
21. Kılıc Y., Cetin H.N., Sumlu E., Pektas M.B., Koca H.B., Akar F. (2019), *Effects of boxing matches on metabolic, hormonal, and inflammatory parameters in male elite boxers,* "Medicina", vol. 55, p. 288; doi: 10.3390/medicina55060288.
22. Larson D.J., Brown S.H.M. (2018), *The effects of trunk extensor and abdominal muscle fatigue on postural control and trunk proprioception in young, healthy individuals,* "Human Movement Science", vol. 57, pp. 13–20; doi: 10.1016/j.humov.2017.10.019.
23. Lepers R., Bigard A.X., Diard J.P., Gouteyron J.F., Guezennec C.Y. (1997), *Posture control after prolonged exercise,* "Eur J Appl Physiol Occup Physiol", vol. 76, pp. 55–61; doi: 10.1007/s004210050212.
24. Lundin T.M., Fuerbach J.W., Grabiner M.D. (1993), *Effect of plantar flexor and dorsiflexor fatigue on unilateral postural control*, "J Appl Biomech", vol. 9, pp. 191–201; doi: 10.1123/jab.9.3.191.
25. Mkaouer B., Jemni M., Hammoudi-Nassib S., Amara S., Chaabene H. (2017). *Kinematic analysis of postural control in gymnasts vs. athletes practicing different sports*, "Sport Sciences for Health", vol. 3, no. 3, pp. 573–581; doi: 10.1007/s11332-017-0383-4.
26. Nardone A., Tarantola J., Giordano A., Schieppati M. (1997), *Fatigue effects on body balance,* "Electroencephalogr Clin Neurophysiol", vol. 105, pp. 309–320; doi: 10.1016/S0924-980X(97)00040-4.
27. Noakes T.D. (2000), *Physiological models to understand exercise fatigue and the adaptation that predict or enhance athletic performance*, "Scand J Med Sci Sports", vol. 10, pp. 123-145.
28. Ochsendorf D.T., Mattacola C.G., Arnold B.L. (2000), *Effect of orthotics on postural sway after fatigue of the plantar flexors and dorsiflexors*, "J Athl Train", vol. 35, pp. 26–30.
29. Ouergui I., Davis P., Houcine N., Marzouki H., Zaouali M., Franchini E., Gmada N., Bouhlel E. (2016), *Hormonal, physiological, and physical performance during simulated kickboxing combat: differences between winners and losers*, "Int J Sports Physiol Perform", vol. 11, pp. 425-431; doi: 10.1123/ijspp.2015-0052.
30. Susco T.M., Mcleod T.C.V., Gansneder B.M., Shultz S.J. (2004), *Balance recovers within 20 minutes after exertion as measured by the balance error scoring system,* "J Athl Train", vol. 39, no. 3, pp. 241-246.

31. Tanner R.K., Fuller K.L., Ross M.L. (2010), *Evaluation of three portable blood lactate analysers: Lactate Pro, Lactate Scout and Lactate Plus*, "Eur J Appl Physiol", vol. 109, no. 3, pp. 551-559; doi: 10.1007/s00421-010-1379-9.
32. Testerman C., Vander Griend R. (1999), *Evaluation of ankle instability using the Biodex Stability System,* "Foot Ankle Int", vol. 20, pp. 317–321; doi: 10.1177/107110079902000510.
33. Vuillerme N., Danion F., Marin L., Boyadjian A., Prieur J.M., Weise I., Nougier V. (2001), *The effect of expertise in gymnastics on postural control*, "Neurosci Lett", vol. 303, pp. 83-86; doi: 10.1016/s0304-3940(01)01722-0.
34. Wilkins J.C., McLeod T.C.V., Perin D.H., Gansneder B.M. (2004), *Performance on the balance error scoring system decreases after fatigue*, "J Athl Train", vol. 39, no. 2, pp. 156-161.
35. Yaggie J.A., McGregor S.J. (2002), *Effects of isokinetic ankle fatigue on the maintenance of balance and postural limits,* "Arch Phys Med Rehabil", vol. 83, pp. 224-228; doi: 10.1053/apmr.2002.28032.

Wydajność posturalna w czasie walki bokserskiej z przeciwnikiem a trening z workiem bokserskim

Słowa kluczowe: boks, kontrola posturalna, walki, rywalizacja

Streszczenie

Tło. Boks z przeciwnikiem może mieć istotny wpływ na kontrolę postawy ciała w porównaniu do treningu z workiem bokserskim. Dla boksera może być istotna wiedza o tym co dzieje się z jego ciałem po walce.

Problem i cel. Przewidywaliśmy, że kołysanie posturalne będzie się zwiększać wraz ze zmęczeniem po walkach z przeciwnikiem i workiem bokserskim. Inną naszą hipotezą było, że kołysanie się po walce z przeciwnikiem będzie większe niż po walce z workiem treningowym.

Metody. Do udziału w badaniu zgłosiło się 11 aktywnych bokserów płci męskiej (wiek = 22,73 ± 4,15 roku), którym zmierzono tętno, mleczan krwi i kołysanie postawy. Kołysanie postawy ciała oceniono przy użyciu systemu *Biodex Balance System* (BBS) na dominującej stopie. W projekcie wewnątrzprzedmiotowym, każdy z uczestników uczestniczył w dwóch warunkach doświadczalnych: boks z przeciwnikiem (*bout*) i boks z workiem treningowym (*bag*). W każdym przypadku zebraliśmy dane sześć razy: przed walką bokserską, po każdej rundzie i 10 i 20 minut po walce.

Wyniki. W drugiej rundzie wyniki OSI były wyższe w przypadku walki z przeciwnikiem niż z workiem treningowym (t = 2.153; p = 0.044). W przypadku walki z przeciwnikiem, wyniki OSI w 1 i 2 rundzie były wyższe niż w rundzie wstępnej (dla 1 rundy, p = 0,031; dla 2 rundy, p = 0,024) oraz w okresie po walce (*Recovery 20*) (dla 1 rundy, p = 0,044; dla 2 rundy, p = 0,006). W przypadku treningu z workiem bokserskim, wartość OSI dla Recovery 20 była niższa niż w pierwszej rundzie (p = 0,027).

Wnioski. Otrzymane wyniki sugerują, że walka z przeciwnikiem nakłada większe wyzwania na kontrolę postawy ciała niż praca z workiem treningowym i że różnice te są niezależne od ogólnego zmęczenia boksera.